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For  $x=2$ , we have  $F(x) = \frac{a(2bc-ab-ac)}{bc}$ . For the numerical values

we have  $F(x) = \frac{1}{8} [1 - (\frac{7}{15})^x]$  and  $F(2) = \frac{1}{15}$ . The value to which

$F(x)$  approximates is  $\frac{bc}{b+c}$ .

38. Proposed by J. A. CALDERHEAD, B. Sc., Superintendent of Schools, Lima, Ohio.

What must be the thickness of a 36-inch shell, in order that it may weigh 1 ton: supposing a 13-inch shell to weigh 200 pounds, when two inches thick?

I. Solution by EDWARD R. ROBBINS, Princeton, New Jersey.

Given shell . . . Vol. =  $\frac{734\pi}{3}$ . Required shell of thickness =  $x$  . . .

Volume =  $\frac{(4x^3 - 72x^2 + 1296x)\pi}{3}$ . Now . . .  $\frac{734\pi}{3} : \frac{4(x^3 - 18x^2 + 324x)\pi}{3} ::$

1:10 which gives . . .  $x^3 - 18x^2 + 324x - 1835 = 0$ , whence  $x = 7.4817$  in. the required thickness.

II. Solution by G. B. M. ZERR, A. M., Principal of High School, Staunton, Virginia, and J. W. WATSON, Middle Creek, Ohio.

Volume 13-inch sphere =  $\frac{1}{8}\pi 13^3 = \frac{2197\pi}{6}$  cubic inches.

Volume of hollow =  $\frac{1}{8}\pi 9^3 = \frac{243\pi}{2}$  cubic inches.

Volume of 36-inch sphere =  $\frac{1}{8}\pi 36^3 = 7776\pi$  cubic inches.

Volume of hollow of 36-inch sphere =  $\frac{1}{8}\pi D^3$  cubic inches.

$\frac{2197\pi}{6} - \frac{243\pi}{2} = \frac{734\pi}{3}$  cubic inches = volume of 13-inch shell.

$\therefore \frac{734\pi}{3}$  cubic inches weigh 200 pounds.

$\therefore$  1 cubic inch weighs  $\frac{600}{734\pi} = \frac{300}{367\pi}$  pounds.

$7776\pi$  cubic inches weigh  $7776\pi \times \frac{300}{367\pi} = \frac{2332800}{367}$  pounds.

$\frac{1}{8}\pi D^3$  cubic inches weigh  $\frac{1}{8}\pi D^3 \times \frac{300}{367\pi} = \frac{50D^3}{367}$  pounds.

But  $\frac{2332800}{367} - \frac{50D^3}{367} = 2000$ .  $\therefore D^3 = 31976$ .  $\therefore D = 31.74$  inches.

$\therefore 36 - 31.74 = 4.26$ ,  $4.26 \div 2 = 2.13$  inches.

$\therefore$  2.13 inches is the thickness of the 36-inch shell.